CORE
Metadata, citation and similar papers at core.ac.uk
Provided by Elsevier - Publisher Connector

ELSEVIER

Available online at www.sciencedirect.com

ScienceDirect

Transportation Research Procedia 14 (2016) 4150 – 4159

Transportation Research Procedia
www.elsevier.com/locate/procedia

6th Transport Research Arena April 18-21, 2016 TRA TRANSPORT RESEARCH ARENA

Why are trees still such a major hazard to drivers in Poland?

Marcin Budzynski [a,]*, Kazimierz Jamroz [a], Lukasz Jelinski [a], Marcin Antoniuk [a]

[a]*Uniwersity of Technology, Gabriela Narutowicza 11/12, 80-233 Gdansk, Poland*

Abstract

Roadside trees are one of Poland's most serious road safety issues. Since 2009 more than 2800 people have been killed as a result of tree collisions; this represents about 15% of all of Poland's accident fatalities between 2009 and 2013. In some of the country's regions striking a tree caused more than 30% of all road accident fatalities. With no proper regulations, guidelines or examples of good practice, roadside environments are posing a serious danger to safety. Trees pose a particular hazard. The paper analyses and evaluates the following factors which cause safety risks on roadsides with trees: strategic level (historic factors – tree alleys, high vehicle speeds, lack of road safety standards), tactical level (region, road class, length of road sections with trees, type of section, time), operational level (road narrowing forcing drivers to use the oncoming traffic lane, limited visibility at junctions and exits).
The paper will present ways to eliminate risks caused by roadside trees and how effective they are in reference to the three levels: strategic level (ensuring that road layouts are clear and homogenous, vehicles remain in their lane, building safe roadside environments, securing hazardous objects), tactical level (building a new road, cutting down trees, putting in safety barriers, speed management, hazard notification), operational level (improving visibility using special marking or cutting down trees where they affect visibility at junctions, using the "2-1" layout, speed reduction, special marking).
Understanding the effects of roads or roadsides on safety requires a detailed study. Sections of national and regional roads were used as a basis for building models to describe the effects of selected road and traffic factors on road safety measures.
© 2016 Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license
(http://creativecommons.org/licenses/by-nc-nd/4.0/).
Peer-review under responsibility of Road and Bridge Research Institute (IBDiM)

Keywords: Crash prediction model; run-off-road; road design; safety zone; road safety

---

* Corresponding author. Tel.: +48-583-471-347; fax: +48-583-471-347.
E-mail address: mbudz@pg.gda.pl

2352-1465 © 2016 Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license
(http://creativecommons.org/licenses/by-nc-nd/4.0/).
Peer-review under responsibility of Road and Bridge Research Institute (IBDiM)
doi:10.1016/j.trpro.2016.05.386

1. Introduction

The risk of becoming involved in an accident is the result of a malfunctioning element of the transport system (man – vehicle – road – environment). The road and its traffic layout and safety equipment have a critical impact on road user safety (Jamroz, 2011). This gives infrastructural work a priority in road safety programmes and strategies at the global (WHO, 2011), European (EC, 2010) and national level (MIR, 2013) Run-off-road accidents continue to be one of the biggest problems of road safety. They lead to secondary collisions when the vehicle rolls over or hits a roadside object (Jamroz et al., 2015). This type of accident represents more than 25% of rural accidents and nearly 20% of all road deaths in Poland. The likelihood and consequences of run-off-road accidents may be reduced where road measures are used to improve safety (Budzynski, Jamroz, 2009). The problem is also addressed in the National Road Safety Programme until 2020 (MIR, 2013) with one of its priorities in the Safe Road pillar setting a run-off-road accident reduction target. This is to be achieved by developing and implementing the concept of “forgiving roads”, i.e. roads with no side obstacles causing a hazard or, if there are obstacles fitting them with passive safety measures. In addition, road signage should be comprehensible and user-friendly. Run-off-road accidents, which include hitting a tree, pole, sign or safety barrier, represent about 10% of all accidents in Poland and more than 19% of road deaths. On a national scale, these accidents are some of the most frequent. A detailed analysis shows that when a vehicle leaves the road it usually hits a tree (nearly 7% of all road accidents in Poland). Hitting a barrier, utility pole or sign is less frequent (Jamroz, 2011; WHO, 2011; MIR, 2013). Roadside trees are one of the most serious problems of road safety. One way to solve it is to use safety barriers. Barriers are used to reduce the consequences of an accident or collision (as opposed to striking a tree in a head-on collision). To that end barriers must be designed and built to respond adequately when struck by a car.

2. Problem description

Run-off-road accidents tend to be very severe because when a vehicle leaves the road, it will often crash into a solid obstacle (tree, pole, supports, front wall of a culvert, barrier). The risks are particularly high in north-west Poland with many of the roads lined up with trees. This may have dire consequences as could be seen in the tragic accident near Gdansk in 1994 when a bus hit a tree killing more than 40 people. Because of the existing rural road cross-sections, i.e. having trees directly on road edge followed immediately by drainage ditches, vulnerable road users are prevented from using shoulders and made to use the roadway. With no legal definition of the road safety zone in Polish regulations, attempts to remove roadside trees lead to major conflicts with environmental stakeholders. This is why a compromise should be sought between the safety of road users and protection of the natural environment and the aesthetics of the road experience. Rather than cut the trees only, other road safety measures should be used where possible to treat the hazardous spots. Accidents that are directly related to the road environment fall into the following categories (based on data from the police database SEWIK): hitting a tree, hitting a barrier, hitting a pole, sign, roll-over on shoulder, roll-over on embankment, in ditch.

Roadside issues are some of the most critical road safety problems. Research has been conducted for a number of years to help identify roadside hazards and ensure effective road user safety measures.

Road safety has been on Poland’s agenda since 1994, following a World Bank mission which defined the gravity of the problem compared to other countries, mainly in Western Europe. Over the years different road safety programmes emerged. The programmes mainly focussed on the need to change how the roadside should be designed, developed and used, especially on single carriageway non-built-up sections, to reduce the severity of run-off-road crashes (Jamroz, Gaca et al., 2005; FRIL, 2007; MIR, 2013).

The main consequence of a roadside hazard is not the likelihood of an accident itself but of its severity (Budzyski, Kustra, 2012) Poland’s roadside accident severity is primarily the result of poor design or operation of road infrastructure. This comes as a consequence of a lack of regulations or poorly defined regulations and failure to comply with road safety standards. As we know from a number of studies looking at how specific road factors affect safety, the roadside environment and its components (vegetation, shoulders, embankments, drainage ditches, poles, signs, engineering objects, etc.) are very critical (Budzyski, Kustra, 2012; AASHTO, 2010; Lee, Mannering, 1999; Viner, 1995; Zegeer, Forrest, 1995).

3. Analysis of statistical data

Between 2010 and 2012, there were 12,160 roadside-related accidents (11% of all accidents within that period). The accidents involved 15,872 injuries (11%), including 4,859 serious injuries (14%) and 2,177 fatalities (19%). With no proper regulations, guidelines or examples of good practice, roadside environments are posing a serious danger to safety. Trees pose a particular hazard. The different types of roadside accidents have caused the following casualties (Fig. 1.):

accidents: hitting a tree: 7,016 (58%), hitting a pole, sign: 2,175 (18%), roll-over (shoulder, embankment, ditch) – 1,941 (16%), hitting a barrier: 1,028 (8%),

fatalities: hitting a tree – 1,623 (74%), hitting a pole, sign – 239 (11%), roll-over (shoulder, embankment, ditch) – 193 (9%), hitting a barrier – 122 (6%).

The severity of accidents was analysed for the different types of run-off-road accidents (measured as the number of fatalities per 100 accidents). The following are the results: hitting a barrier – 12, hitting a tree - 23, hitting a sign, pole – 11, roll-over - 10. As the figures show, run-off-road accidents are clearly most severe when they involve hitting a tree.

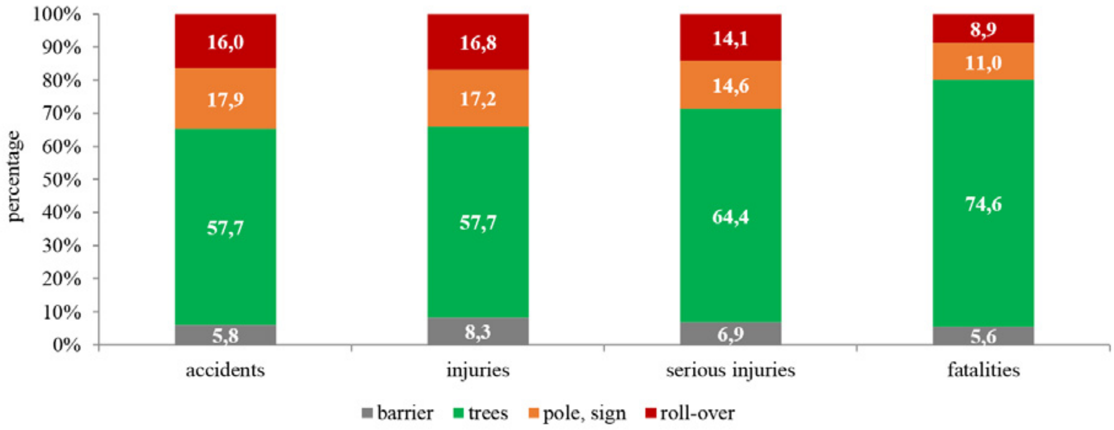

Fig. 1. Types of roadside-related accidents.

The next analysis looked at roadside accidents by road category. The following categories are applied: national roads, regional roads and other roads (county and municipal). Run-off-road accidents are most common on regional roads (15%), followed by national roads at 9% and other roads at 10%. As regards fatalities, the majority occurred on other roads at 24%, regional roads at 22% and national roads at 11%. Safety of national roads is much better than in the other categories. This is because more investments are made to upgrade these roads and the removal of roadside trees is easier. Roadside accidents were also analysed for regional distribution. It was found that in the years 2010 - 2012 (Fig. 2): the highest share of fatalities was recorded in the regions of Zachodnio-Pomorskie - 153 (34% of all fatalities), Warminsko-Mazurskie - 157 (33%), Pomorskie - 163 (27%), Lubuskie - 89 (27%).

Analysis of roadside accident location confirmed that the north-west and north-east of Poland is at particular risk with the regions of Warminsko-Mazurskie, Zachodnio-Pomorskie, Lubuskie and Pomorskie clearly having the worst record. New measures are required to reduce the hazards posed by dangerous roadside environments.

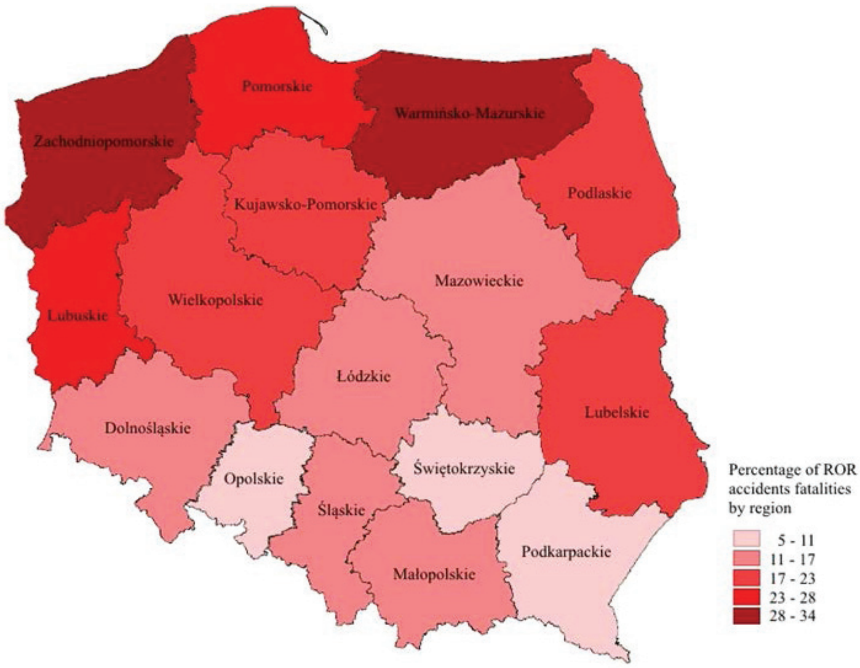

Fig. 2. Roadside-related accidents and victims by region.

4. Hazard identification

A number of in-the-field tests were conducted looking at road infrastructure and its safety. Based on the findings, a number of elements were identified which present a potential roadside hazard to road users. In 2013 a road safety inspection method was developed and implemented. The development of the Polish method took into account the experience of other countries (RSI, 2012; Cafiso et al., 2006; RSI, 2012). Selected sources of hazards were illustrated with photographic documentation (Fig. 3.). The sources of Poland's most prevalent roadside hazards include:

- trees close to the edge of the road (up to 3 metres away from the edge of the carriageway the risk is the highest, especially in the area of bends in horizontal alignment, junctions and exits),
- other green restricting visibility,
- elements of infrastructure which are unyielding (concrete or wooden poles, masts, etc.),
- supports of civil engineering objects too close to the edge of the road, unsecured (e.g. bridge supports),
- drainage facilities – vertical concrete front walls of culverts,
- steep embankments,
- poor technical condition of shoulders,
- inadequately terminated, too short, wrong operating width and damaged road barriers.

As well as being the direct cause of an accident, these sources of hazards cause other types of accidents because of where they are. This includes head-on collisions if there are structures within the road, hitting a pedestrian or bicyclist because there is no space for the vehicle to use beyond the carriageway.

When these types of accidents are reported, the statistics does not take account of the roadside as a cause or circumstance (e.g. no trees were hit but it was the trees that restricted visibility and eventually led to the accident). As a result, roadside conditions are underreported in road accident databases.

Fig. 3. Examples of hazards due to roadside trees.

5. Methods to solve the problem

Roadside safety management can be delivered at three levels: strategic, tactical and operational. It is based on the Directive of the European Parliament 2008/96/EC and is part of road safety management in the broad sense (Jamroz, 2011).

Strategic risk management occurs primarily when road networks are planned and operated. This is delivered by central authorities and central road authorities. The main factors of hazard at the strategic level that contribute to the severity of run-off-road accidents include: existing infrastructure which “forgives” drivers their mistakes on some sections only, legacy – avenues with roadside trees, speeding because drivers notoriously drive over the speed limit, lack of safe roadside design standards or guidelines, conflicts with environmental services (the hermit beetle, an insect, is more important than human life and trees cannot be removed in its habitat).

Roadside hazards are also caused by poor design, construction and maintenance of roadsides. This problem is addressed in a number of programmes and road safety plans. The National Road Safety Programme GAMBIT 2005 (Jamroz, Gaca et al., 2005) dedicates two of its five strategic objectives to the problem of accidents involving striking a tree: construction and maintenance of safe road infrastructure, reduction of accident severity (by e.g. a “soft” roadside and “forgiving” roads).

The GAMBIT National Roads programme’s objective number 3 aims to “Reduce road deaths as a result of running off the road”. It is to be achieved through more recognisable, clearer and more consistent roads, vehicles staying in lane (signage, narrow hard shoulders), safe roadside (safe embankments, safe drainage facilities, removal of hazardous objects (including trees) and securing hazardous objects (barriers, crash terminals).

Reinforced by the GAMBIT National Roads programme, the National Road Safety Programme GAMBIT 2005 helped to reduce run-off-road fatalities within 10 years by 30%. It is estimated that by removing roadside hazards (removing trees and securing trees and utility poles) 2 250 people could be saved from death.

Operational risk management occurs primarily when road networks and parts of roads are planned and operated. This is delivered by regional authorities and regional road authorities. The main factors of hazard at the tactical level that contribute to the severity of run-off-road accidents and require action include: the region of the country; these problems occur in the north and west of the country, as an example in the region of Pomorskie sections of roads with trees that are less than 1.5 m away from the road occur on 20% of national roads, 40% of regional roads and 65% of local roads, road category, roadsides are safer (fewer obstacles, more safety measures) on national roads of higher technical class, regional and local roads are severely affected, type of road section (straight section or horizontal bend), limited visibility, especially at night-time.

The main actions at the operational level include the design, construction and operation of roads to take account of high risk road sections; risk maps are very helpful with that, prepared in the EuroRAP project (Fig.4.), removing hazardous objects: felling trees, rearranging the objects or relocating the road away from the objects, securing hazardous objects by using safety barriers and other structures, speed management and hazard notification and implementing roadside safety standards. A permit is required to fell roadside trees posing a hazard to road users. While obtaining a permit may be a problem, a recent Supreme Chamber of Audit report may be helpful because it addressed the problem of roadside hazards (EASTA, 2005).

Tactical risk management occurs primarily when road networks and parts of roads are built, operated and reconstructed. This is delivered by local authorities and local road authorities. The main factors of hazard at the tactical level that contribute to the severity of run-off-road accidents and require action include: narrowing of road and roadside which forces vehicles to drive on the opposing traffic lane (head-on collisions), reduced visibility at junctions and exits (side impact), road signs covered up (road not clear and understood), no space for pedestrian traffic and reduced visibility at pedestrian crossings (hitting a pedestrian) and causing damage to road infrastructure.

The main actions at the tactical level include construction and operation of roads to take account of: better visibility through special signage or removing trees at junctions to ensure visibility, using the 2-1 cross-section on local and regional roads (tests have been conducted in Chojnice area, use of local speed limits (70 or 50 km/h), special signage – least effective.

The success of tactical level management depends on the quality of efforts at the higher levels. The resources at this level are quite scarce and funding for prevention and treatment is insufficient. As a result, local roads are usually treated by putting up signs, reducing speed and felling trees which happens less and less often. Poland's efforts to reduce roadside hazards frequently build on European initiatives (Elvik, 1994).

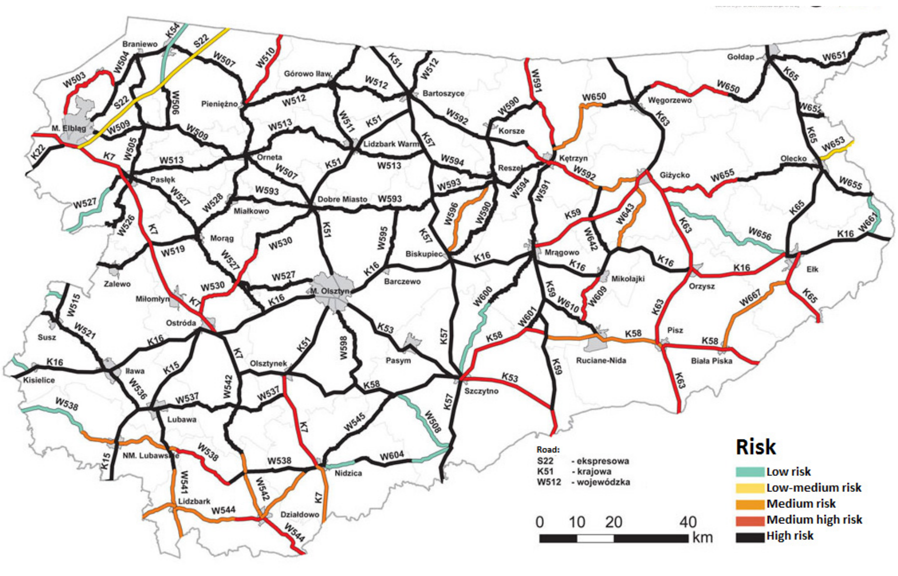

Fig. 4. Map of individual risk on national and regional roads – run-off-road accidents in the region of Warminsko-Mazurskie. *Source: eurorap.pl*

6. Modelling the effects of selected roadside elements on road safety

Analyses of models of how roadside elements affect road safety (EASTS, 2005; Elvik, 1994; Karim et al., 2012; RISER, 2006) showed that the methodologies and data differ from model to model. Because the models focus on different factors, they each have strengths and weaknesses.

The new analytical model was designed as a combination of the different factors and one that will serve as a comprehensive model for Polish conditions. It was assumed that it will describe the effect of the roadside on the number of accidents and their consequences. The design of the model was based on recommendations from analysing other models. The assumptions were the following: the model will be used to calculate risk factors and accident severity, the indicators will depend on number of vehicle kilometres travelled or traffic volumes, analyses will be based on accident data: striking a tree, hitting a barrier, hitting a utility pole or sign. Additional data will include roadside information and casualty density measures will be used – killed and injured.

6.1. Description of the study

The study was conducted for national roads in the region of Pomorskie. The first phase of the study was designed to build an inventory of roads and build accident databases. The next stage was to develop mathematical models to show the correlations between roadside and accidents. All analyses were based on the SEWIK database. The accident database included information about accidents and collisions involving running off the road. A period of three years (2010-2012) was selected and served as the basis for all calculations and models.

The inventory covered sections of national roads at the total length of about 777 km (except national roads in urban areas). There were separate inventories for the left and right edge of the roadway and the central reservation (in the case of dual carriageways). Potential roadside hazards were identified (trees, embankments, utility poles, engineering structures) and selected type of barriers (concrete, steel, ropes).

To ensure that data were collected consistently, two databases were built: roadside database and accident database. The primary data that were imported into the databases at the start included Road Data Bank information about reference sections with details on: section length, traffic volume, number of vehicle kilometres travelled and share of hard shoulders.

With the large set of data already in place, reference sections were used for collecting roadside information and creating computational models. The roadside database had about eight thousand records – measurement sections assigned to reference sections 1 – 5 km long. The records contained data about section length, annual average daily traffic flow, number of junctions, exits, signs, utility poles and percentage share of sections with barriers, trees, embankments and hard shoulders depending on their width.

6.2. Model of the effects of roadside on road safety

The chapter presents the analyses and results of the GOF victim density rate. The objective of the model is to estimate the expected number of victims of accidents on national roads per kilometre of road over a specific period. The victim density model is described with the following formula:

$$GOF(Y) = \alpha \cdot Q^{\beta_1} \cdot e^{(B^{\beta_2} + S^{\beta_3} + T_1^{\beta_4} + T_2^{\beta_5} + T_3^{\beta_6} + C^{\beta_7} + P_1^{\beta_8} + P_2^{\beta_9} + P_3^{\beta_{10}})} \quad (1)$$

where:

GOF(Y) expected number of accident victims per kilometre of road (dependent variable)

α adjustment coefficient

Q annual average daily traffic (AADT)

βj (1,2,…,n) calculation coefficients

B,S,T_1,T_2,T_3 factors related to the risk of an accident (independent variables)

C,P_1,P_2,P_3

the model has a determination coefficient (R2) equal to 0.85.

Table 1. Parameter estimates of the crash prediction models of Eq. (1).

	Coefficients		Value	Lower confidence limit	Upper confidence limit	p-Value
	Adjustment	α	1.14E-07	1.14E-07	1.14E-07	0.00
Traffic volume	Q	β_1	0.67	0.31612	1.03195	0.00
% of barriers	B	β_2	-3.02	-4.48932	-1.55423	0.00
% of embankments	S	β_3	1.73	0.48282	2.99325	0.00
% of trees to 3.5m	T_1	β_4	2.85	1.98812	3.71178	0.00
% of trees above 3.5m	T_2	β_5	1.25	0.62473	1.87844	0.00
% of forests	T_3	β_6	-0.46	-1.46917	0.54344	0.00
Road class	C	β_7	8.66	2.70382	14.62712	0.00
% of shoulders above 1.5 m	P_1	β_8	-0.63	-0.92808	-0.32719	0.00
% of shoulders to 1.5 m	P_2	β_9	-0.46	-1.05439	0.13582	0.00
% of soft shoulders	P_3	β_{10}	0.17	-0.75521	1.09778	0.00

6.3. Results of the study

The effectiveness of road safety measures largely depends on how intensively evaluation tools are used to understand the benefits. These tools include prognostic models. They can be used to identify high risk sections or study the relation between road section features and the potential for accidents.

An analysis of the study in Pomorskie shows that victim density declines as the percentage of section with barriers and hard shoulders increases. The results of the study are presented below (Fig. 5.) for single carriageways in outside built-up areas of class GP (trunk road with higher speed limits). The number of victims depends on trees within a distance of up to 3.5 m, embankments and trees further away (more than 3.5 m from road edge).

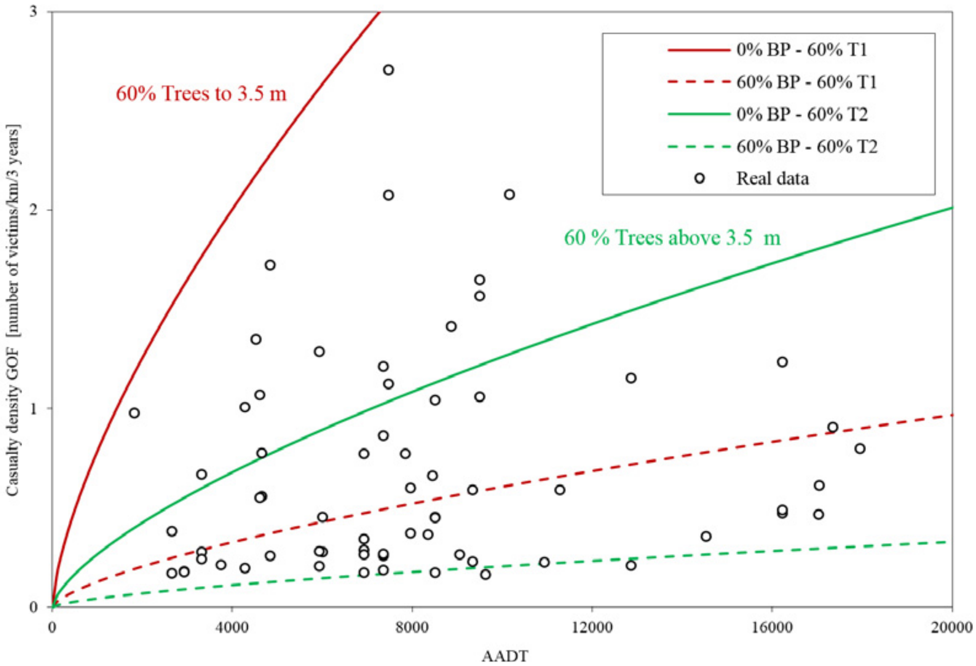

Fig. 5. Casualty density in relation to the distance between the tree and road edge and percentage share of barriers.

A number of road projects struggle with the choice of the most effective safety measures. Choosing the cheapest option may turn out to be hazardous for road users. The consequences and direct and indirect costs of accidents may exceed the original financial gains. If equipped with the right tools, each of the options can be assessed for its pros and cons (cost and benefit analysis, multiple criteria analysis).

Cost analysis of safety barriers is an excellent example. Just as any other road safety equipment, barriers are an additional cost when new roads are built or upgraded. The price, lack of good will on the part of road authorities or lack of knowledge are usually the reasons why safety barriers are frequently ignored. Ana

lyses show that putting in safety barriers may reduce the number (density) of victims compared to the same sections with the same hazards and no safety barriers: it is three times in the case of trees more than 3.5 away from the road edge, five times in the case of embankments and as many as seven times in the case of trees up to 3.5 m from the edge.

7. Summary and conclusions

Over the last twenty five years more than 20 000 people were killed on Polish roads in run-off-road crashes (of which a clear majority involved hitting a tree). Analyses and studies of roadside hazards offer the following conclusions:

- the main factors that influence the risk of being involved in such a crash are: historic developments, road class length and element of carriageway, hazardous elements at the edge of carriageway (mainly trees), safety measures in place or lack of safety measures,
- the risk is the highest in the north and east of Poland considering the entire road network and in the east of Poland in the case of national roads,
- with no regulations. design standards and cooperation with environmental organisations and institutions, human life is valued below that of trees, lichens and insects,
- the next models must includes vehicle structure (HGV, motorcycles) and other road users (cyclists and pedestrians) influencing the driver's behavior,
- to improve roadside safety we must: identify the hazards on the road network, conduct checks, conduct research (build models of the effects of selected factors on road safety, effectiveness evaluation), implement safety standards, develop guidance and principles for safe roadsides, ensure that there is collaboration between designers, road authorities and environmental organisations and institutions, exchange experience with other countries.

For years roadside environments have been one of the most neglected aspects of road safety efforts in Poland. Clarity is needed on the effects of roadsides on road safety. We must understand the hazards roadsides cause and implement effective solutions.

References

AASHTO, 2010. Highway Safety Manual.Washington, D.C. American Association of State Highway and Transportation Officials AASHTO.

Budzynski, M., Jamroz, K., 2009. Strategia zmniejszenia liczby i skutkow wypadniecia pojazdu z drogi. (The strategy to reduce the number and effects of run-off-road) „Drogownictwo", R. 64 (4-5) pp 134-142.

Budzynski, M., Kustra,W., 2012. Analizy zagrożeń na jednorodnych odcinkach drogowych (Hazard analysis on homogeneous road sections.) "Drogownictwo" 4/2012, Warsaw.

Cafiso, S., La Cava, G., Montella, A., Pappalardo, G., 2006. Operative Procedures for Safety Inspections on Two – Lane Rural Roads, IASP, Catania, Italy.

Directive 2008/96/EC of the European Parliament and of the Council, On road infrastructure safety management, Brussel 2008

EASTA (Eastern Asia Society for Transportation Studies), 2005. Development of traffic accident prediction models by traffic and road characteristics in urban areas, Vol.5, pp. 2046-2061

EC (European Commission), 2010. Road Safety Programme 2011 – 2020. Brussels.

Elvik, R., 1994. The safety value of guardrails and crash cushions: a meta-analysis of evidence from evaluation studies, Institute of Transport Economics, Norway.

FRIL (Foundation for the Development of Civil Engineering), 2007. GAMBIT Drogi Krajowe (GAMBIT National Road), Drogownictwo.

Jamroz, K., 2011. Metoda zarzadzania ryzykiem w inzynierii drogowej (Risk management methods in engineering road). Gdansk University of Technology.

Jamroz, K., Antoniuk, M., Jelinski, L., & Gronowska, K., 2015. Wypadnięcie pojazdu z drogi i jego konsekwencje - rozpoznanie problemu na odcinkach drog krajowych wojewodztwa pomorskiego (Run off road and its consequences - recognize the problem sections of national roads Pomeranian province.) „Drogownictwo" 4-5/2015.

Jamroz, K., Gaca, S., Dabrowska, M., Budzyński, M., 2005. GAMBIT 2005 – Krajowy Program Bezpieczeństwa Ruchu Drogowego (GAMBIT 2005 – National Road Safety Programme), Gdansk and Cracow University of Technology, Motor Transport Institute.

Karim, H., Magnusson, M., Wiklund, M., 2012. Assessment of Injury Rates Associated with Road Barrier Collision. Procedia – Social and Behavioral Sciences, no. 48.

Lee, J., Mannering, F., 1999. Analysis of roadside accident frequency and severity and roadside safety management, Research Project T9903, Washington State Transportation Center (TRAC), Washington

MIR (The Ministry of Infrastructure and Development), 2013. Narodowy Program Bezpieczenstwa Ruchu Drogowego. Ministerstwo Infrastruktury (National Road Safety Programme. The Ministry of Infrastructure and Development), Sekretariat Krajowej Rady BRD, Warsaw 2013.

RISER, 2006. Roadside Infrastructure for Safer European Roads – Envelope of Vechicle and Driver Response Prior to Collisions, Chalmer University of Technology 2003 – 2006.

RSI, 2012. Road Safety Inspection Guideline For Safety Checks of Existing Roads, World Road Association (PIARC), France

RSI, 2012. Road Safety Inspection RVS 02.02.34 Bundesministerium für Verkehr, Innovation und Technologie, Österreichische Forschungsgesellschaft Straße- Schiene – Verkehr.

Viner, J. G., 1995. Rollovers on side slopes and ditches , Accident Analysis and Prevention, Vol. 27, No. 4, 483-491.

WHO (World Human Organization), 2011. Global Plan for the Decade of Action for Road Safety 2011-2020. Washington.

Zegeer, C. V., Forrest, M., 1995. Council Safety relationships associated with cross-sectional roadway elements , Transportation Research Record 1512, 29-36.